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DIJKSTRA'S ALGORITHM BASED ON 3D CAD NETWORK MODULE FOR SPATIAL INDOOR ENVIRONMENT

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ABSTRACT

Dijkstra's algorithm has been widely used in many applications. Solving the mathematical (graph) problems and finding a shortest route in personal navigation are the most common applications that utilized this algorithm to perform the analysis. For some areas such as industrial transportation, emergency navigation and navigation planning, a well-planned navigation is important. Dijkstra's algorithm is a part of network analysis capabilities, can minimize the transportation cost, the disaster or accident impact and able to provide right decision for the best route in certain situations. However, there are several algorithms that capable of finding the best way from one location to another. Dijkstra's algorithm is one of the algorithms that can be used in network analysis and have proven its capabilities especially for 2D shortest route analysis. Analysis for three-dimensional (3D) network is required when it involves indoor navigation i.e. inside of a high-rise building. The complexity of building architecture and their surroundings requires

a well-defined network to analyze it in 3D environment. There are several attempts to utilize Dijkstra's algorithm on 3D network. The aim of this study is to investigate the Dijkstra's algorithm by using 3D CAD network data module.

Keywords: Dijkstra's algorithm, 3D CAD Network, and Spatial Indoor Environment

1.0   INTRODUCTION

Implementation of network analysis (i.e. shortest path analysis) mostly based on application objectives and situation. For instance, disaster based or emergency applications in urban areas need shortest path routine to navigate in a complex surrounding architecture. System that could provide a route network within a building helps to locate safety routes for example to people in fire and rescue missions and other emergency operations. Shortest path routines are useful in assisting human navigation. There are several kinds of navigations. Other navigation applications in this domain like pedestrian navigation, and even for car navigation on roads or in racing circuit using computer game engine is worth to mention. Balstrom (2001) listed some of the applications that need this kind of routine e.g. searching the nearest restaurant, a petrol station, jungle trekking on the mountain/hills, locating the emergency exit doors during fire (emergency) in a building. Shortest path network for multilevel buildings thus the connectivity between levels or floors are certainly be very useful and interesting to be investigated. Dijsktra algorithm could be used for this sort of applications that is by extending to three-dimensional (3D) environment. Some researchs on Dijsktra algorithm for 3D environment have been done such as Karas et al. (2006). Other related work such as Meijers et al. (2005) and Pu and Zlatanova (2005)

focused on indoor navigation routing. This research describes the experiment on Dijkstra algorithm based on 3D CAD network data. The experiments were based on micro-spatial environment (i.e. inside of a building).

2.0   MOTIVATION

The incorporation of 3D visualization and analysis with GIS can greatly improve the users' comprehension on the spatial problems that occur and assist them in decisions making process. The visualization also improves the reliability of the GIS application as an effective decision making tool. 3D Geographical Information System (3D-GIS) development is at early stage and various groups try to address some aspects of 3D GIS e.g. based on Virtual Reality (VR) and terrain visualization. Africawala et al. (2004) view 3D-GIS as component of 3D Data Capture, 3D Visualization and 3D Data Modeling and Management. 3D Data Capture is component of automatic generation of terrain models from aerial imagery or laser scanning. 3D Visualization concentrates on how to visualize 3D objects and performance of 3D visualization on mobile devices. The 3D Data Modeling and Management components are on the model and management of complex 3D objects in a relational DBMS environment.

3.0   THE DIJKSTRA ALGORITHM

If the vertices of the graph represent cities and edge weights represent driving distances between pair of cities connected by a road, then Dijkstra's algorithm can be used to find the shortest route between the two cities. The same scenario could be established for building e.g. two nodes on the same floor or on different floors. The cost of an

edge can be thought of as (a generalization of) the distance between
those two vertices. The cost of a path between two vertices is the sum
of costs of the edges in that path. For a given pair of vertices s and t in
V, the algorithm finds the path from s to t with lowest cost (i.e. the
shortest path). It can also be used for finding costs of shortest paths
from a single vertex s to all other vertices in the graph, Figure 1
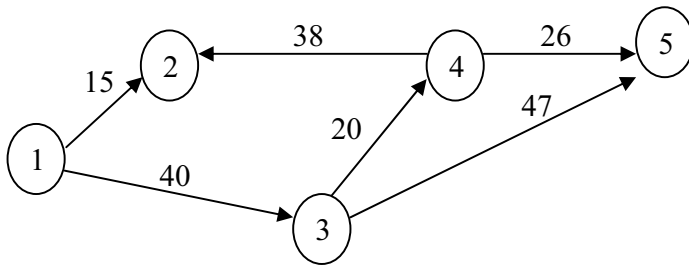illustrate the connected nodes.

Figure 1: Several connected nodes.

For the network on Figure 1, let us assume that we want to go from
node #1 to node #5, here node #1 is the source node, and the
destination is node #5. The algorithm considers all the nodes known as
unlabeled nodes. Firstly, the calculation begins with node #1 (source
node) and this node automatically be labeled as permanent and could
be noted as [0, -]. The distance value is 0 and there is no value for the
predecessor node label because it does not yet move from the source
node location. Then after node #1 has been labeled as permanent, then
it will look for the successor of node #1. In this case, the successor is
node #2 and node #3. Then it will choose node with the shortest
distance (d) between node #1 and with its successor nodes. The
distance (d) is being calculated by adding the d value for node #1 label

with the distance between node #1 and node #2 or node #3. For node #2, the distance is $0 + 15 = 15$ and for node #3 its $d = 0 + 40$. Thus, in this case the shortest distance between node #1 with it successor is node #2 (i.e. $d = 15$). Node #2 will be labeled as permanent [15, 1] and node #3 will be labeled as temporary. Thus at this stage, the unlabeled nodes are #4 and #5.

The next step is to get the last permanent node (i.e. node #2). Here, the same procedure will be applied, i.e. to check the potential node candidate. In this case, there is no node after nodes #2 – because of the opposite direction. The candidate (i.e. pointer) at node #1 looks for alternative route i.e. node #3 (with $d = 40$). When the pointer is at node #3 then it will look for the shortest route and in this case it could be node #4 or node #5. So, obviously the candidate for the next node will be node #4. The process continues until at the end of the network. So in this case the algorithm will stop and the result for this network is a spanning tree as shown in Figure 2.
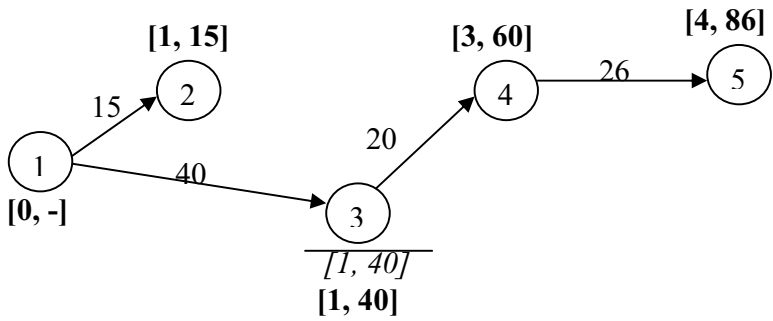
* *Italic* labeling indicates a temporary label
* **Bold** labeling indicates a permanent label

Figure 2: Spanning tree.

Figure 2 shows the entire route (from node 1 to the other nodes). Thus, the loop for the network is node #1 > node #3 > node #4 > node #5.

4.0   3D CAD NETWORK

Computer-aided design (CAD) is a computer technology that aid in the design of a product. Many areas used CAD to do the drafting in conceptual design phase. CAD been use as a replacement for traditional drafting that is time consuming. CAD enables designers to work on computer screen, print and save it for future editing, saving time on their drawings. Among fields that used CAD such as engineering-based, industrial design, software applications and including mapping in geographical information system (geoinformation science).

GIS and CAD more used in developments of plans and products (i.e. bridges, tunnels) as well as visualization, surveying and location-based services, Zlatanova and Prosperi (2006). Software used to generate 3D network in this research is Autodesk Map 2004. This software is a CAD software and capable to generate 3D network by using 3D polyline function. Based on this 3D network data structure, it can be manipulate to perform the Dijkstra's algorithm calculation analysis. The basic structure for 3D network is the group of connecting nodes (points) of the line that consists of x, y and height value (point coordinates). AcDb3dPolyline refers as the header file for the points in this 3D network. 3D points coordinates value is within the header file with Vertex (footer). This enables systems to recognize and select desired information from the 3D CAD data structure.
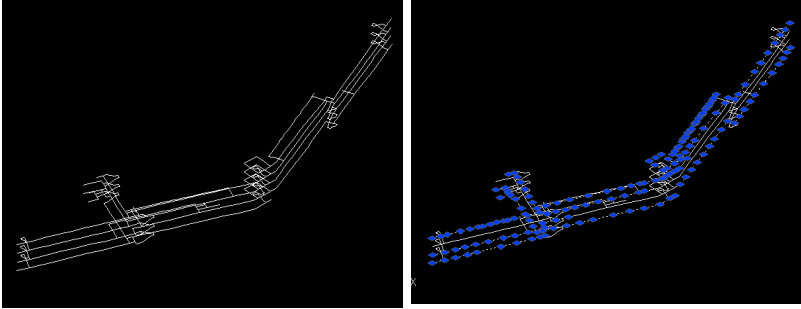
Figure 3: Generated 3D CAD network (Left) and some selected nodes in the network (Right)

5.0   THE EXPERIMENT

5.1   Study Area

The study area in this research is Faculty Geoinformation Science and Engineering (C02, C03, C04, C05 and C06 building) at Universiti Teknologi Malaysia, Skudai, Johor. The analogue plans (floor plans) have been converted to digital via digitization process and constructed to 3D. Real texture is attached to the building (to have a more realistic view) as we perceived in the real world as shown in Figure 4.
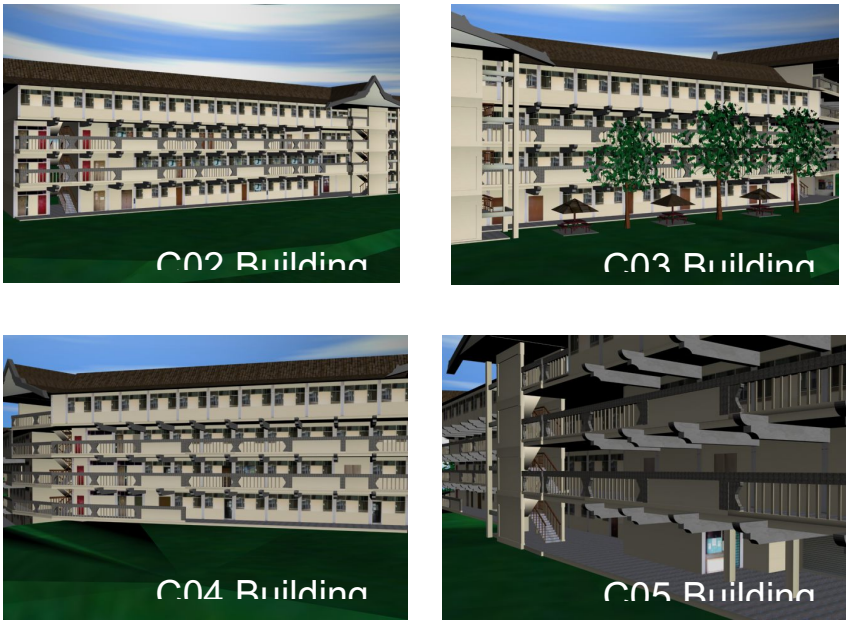
Figure 4: The constructed 3D building models.

5.2   Dijkstra's Algorithm for 3D Network

After we have established a 3D network for the area (3D building) important information like IDs, distances, and potential candidates of nodes need to perceive. This information is fundamental in this problem domain. However, all of this information is available in the 3D network and need to be extracted and to be assigned with proper IDs. By putting ID to each node, then the network is now applicable for Dijkstra's algorithm.

The next step is to calculate the distance between connected nodes (i.e. successor and predecessor nodes). It is not necessary to calculate the distance between all the nodes in the network as this will consume a lot of time. If node #1 is connected to node #2 and node #3, then the calculation will be based on those three nodes. To accomplish that, information on predecessor and successor nodes is important. To make computers understand which nodes are connected or not, therefore the network data file must be examined thoroughly. From here the data file will be examined in order to find which part of the data is useful or not, and to determine which node is connected/reachable or not.

The distance between nodes for 3D network can easily calculated by using simple mathematical formula, see Figure 2.

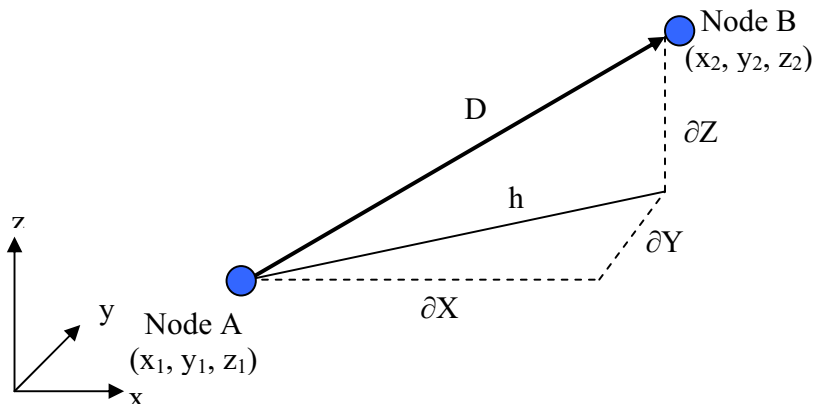Example: distance between node A (x_1, y_1, z_1) to node B (x_2, y_2, z_2),

Figure 5: 3D point differential for node A (x_1, y_1, z_1) and node B (x_2, y_2, z_2) in 3D axis.

Delta (∂) for x, y and z can be calculate by finding the differential between nodes,

$$\partial X = (x_2 - x_1) \; ; \; \partial Y = (y_2 - y_1) \; ; \; \partial Z = (z_2 - z_1)$$

Then the distance (D) could be derived by two equations as below:

$$D = \sqrt{(h^2 + \partial Z^2)} \ldots\ldots\ldots\ldots\ldots \text{Equation 1}$$

h can be derived by:

$$h = \sqrt{(\partial X^2 + \partial Y^2)} \ldots\ldots\ldots\ldots..\text{Equation 2}$$

By combining both equation 1 and 2, the final equation to find the distance (D) between the nodes is:

$$D = \sqrt{[(\partial X^2 + \partial Y^2) + \partial Z^2]} \qquad \text{or} \qquad D = \sqrt{[(x2 - x1)^2 + (y2 - y1)^2 + (z2 - z1)^2]}$$

Then from here, the Dijkstra's algorithm can be executed successfully as in the case of 2D network.

5.3   The Experiment

In general, the experiment process is illustrated in Figure 6. 3D network is for the data input. The main application will act as the engine to process the 3D shortest path analysis. Then, as a result, calculation statistic will be displayed along with 3D network (graphics) with the result (shortest path) highlighted.
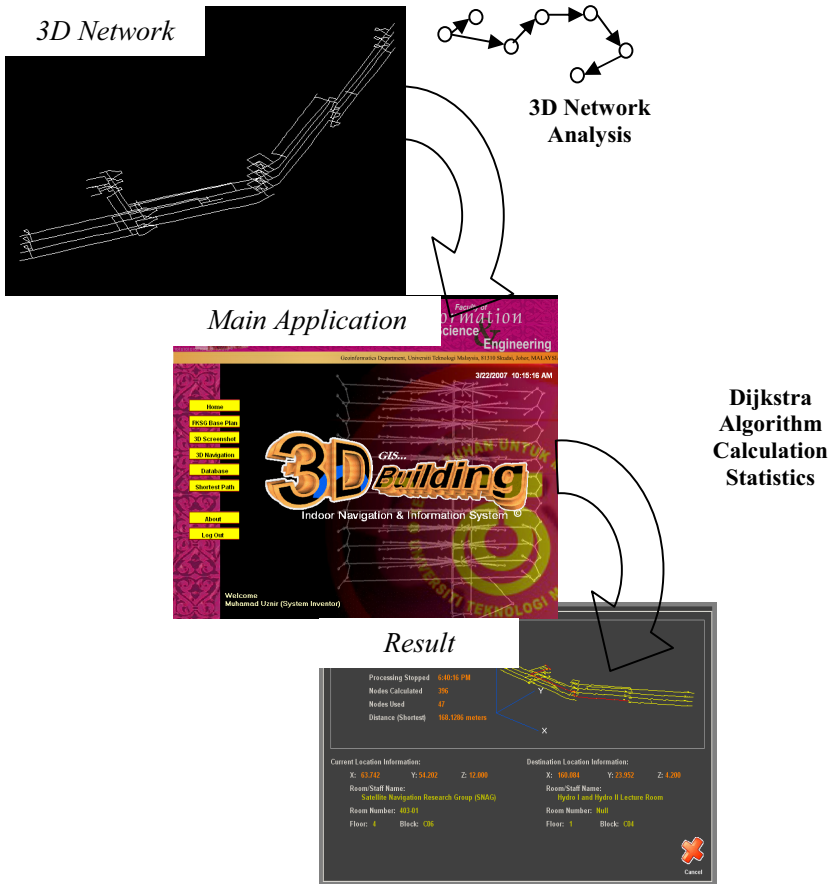
Figure 6: Experiment process

A user needs to select their current location and destination locations (e.g. based on Room's ID or Staff Name) prior to begin the Dijkstra's shortest route calculation (see Figure 7). The information at the combo box in the Shortest path windows and Advance Search windows is based on the 3D network file that set by the user during the database initialization. After the required information for the current and destination location has been set, the Dijkstra's algorithm can be executed/run for the 3D Network calculation in the main application. As a result, it shows the Dijkstra's Shortest Path Calculation Result windows for the 3D network based on the user current location and destination location.
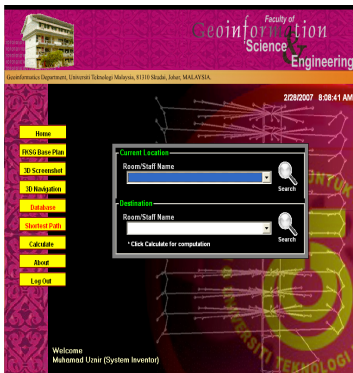

Figure 7: Set Current and Destination Location

Figure 8: Advance Search

The shortest path calculation windows displays the information about the *Status*, *Date*, *Calculation* time, *Nodes Calculated*, *Nodes Used*, *Shortest Distance*, and both information about current and destination location (including the x, y and z coordinates). The Status of the calculation is the information whether the executable calculation is

successful or the destination location is not reachable for the user to navigate to. *Shortest Distance* shows the distance (shortest) in meters from current location to destination location. The system also able to show the shortest route graphically in the 3D network as illustrated (see Figure 9). The shortest route of the 3D navigation is highlighted in red colour.
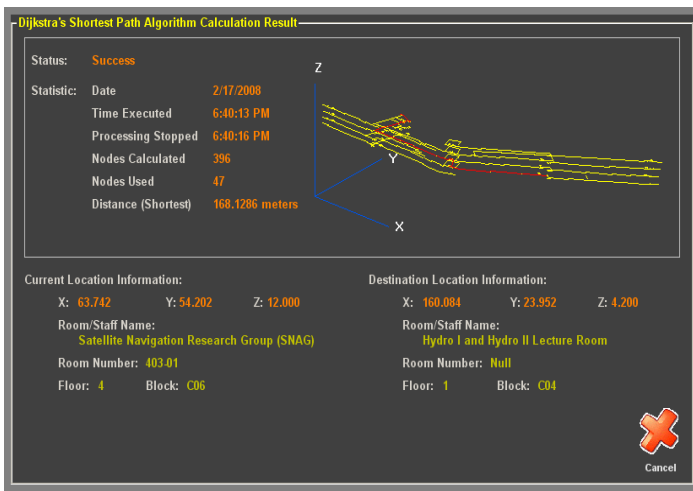

Figure 9: Calculation Result

6.0   CONCLUDING REMARKS

From the result presented in the preceding section, it appears that the Dijkstra's algorithm can be implemented in the 3D network environment. It acts mostly like Dijkstra's algorithm implementation into 2D environment. The difference for 3D network is that it needs extra calculations for distance to include the z coordinates value by using the mathematical formula.

GIS and CAD have been developed and used in different areas and organisations; a growing tendency has emerged in trying to integrate them and used them in projects. In this project Dijkstra's algorithm are implemented for 3D indoor environment by using 3D CAD network. It could be extended for much larger 3D world. Manipulation of CAD data structure makes it possible to perform the network analysis by extracting required information.

The approach works and certainly is useful for any agencies and personnel who deal with stress or non-stress operations like building emergency rescue and missions, evacuations and training purposes. Implementation of Dijkstra's algorithm in 3D network makes the shortest path analysis for multi-levels buildings can be more accurate and efficient for navigation or simulation in a building.

Further research to integrate volume in 3D environment with 3D network could produce better GIS application in future. With some support from 3D database, many analyses in 3D environment can be addressed and hopefully this kind of research would enhance 3D GIS development and 3D network analysis specifically. Our future work is to extend the approach by utilizing different kind of 3D network data and to be able to manipulate 3D objects for indoor and outdoor environments.

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